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ENERGETIC VALORISATION OF SEMI-RIGID AND FLEXIBLE ALUMINIUM PACKAGING BY OXIDATION AT HIGH TEMPERATURE

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OBJECTIFS

The study of energetic valorization of semi-rigid and flexible aluminium packaging by oxidation at high temperature, simulating operation conditions of incineration plants of MSW.

SAMPLES

23 types of semi-rigid and flexible aluminium packaging obtained at Spain's 10 MSW incinerator

Separation and characterisation of the different waste components

Treatment into 1M HCl solution

- Selective disolution of metallic aluminium → metallic aluminium content
- undissolved non-metallic components → polymer/paper content

Clasification

Semi-rigid packaging | Flexible Low Al content | Flexible High Al content

Physical Properties (mean values)

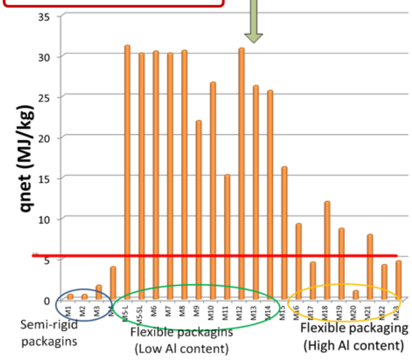
Packaging formats	Weight [g]	Surface density [kg/cm^2]	Thickness of Al lamina [µm]	Metallic Al [wt,%]	Polymers [wt,%]	Cellulose [wt,%]
Semi-rigid (samples 1 - 4)	5.6±1.4	0.22±0.05	72.8±14.1	94.8±4.7	5.2	0
Flexible A[a] (samples 5 – 15)	5.1±2.6	0.10±0.03	5.70±4.1	9.2±9.0	76.1	14.7
Flexible B[b] (samples 16 – 23)	1.9±1.6	0.09±0.06	59.1±37.4	82.5±9.2	15.2	2.3

Net calorific value, required energy, and the calorific gain
Standards BS EN 13431:2009 and UNE EN 13431:2004

Packaging format	Σ q_{net} [MJ/kg]	H_a [MJ/kg]	Calorific gain [MJ/kg]	contribution made by the Al [%]
Semi-rigid (samples 1 to 4)	1.7±1.3	1.3±0.6	0.4±0.2	≈ 0
Flexible A[a] (samples 5 to 15)	26.3±5.4	12.8±4.1	13.5±2.8	2.6±0.1
Flexible B[b] (samples 16 to 23)	6.6±3.3	3.6±1.2	3.0±2.1	18.8±0.2

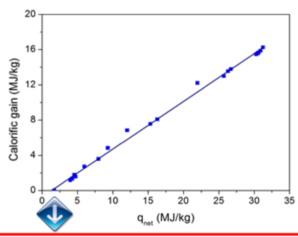
$$4Al + 3O_2 \rightarrow 2Al_2O_3 + heat \quad \Delta H_f^0 = -1675{,}5\ kJ/mol$$

Net calorific value of a packaging



Packagins with a qnet ≥ 5 MJ/kg shall be considered recoverable in the form of energy (UNE EN 13431:2004)

The contribution of the oxidation of aluminium (an exothermic reaction) to the calorific gain depended on the type of packaging, and, therefore, on the thickness of the aluminium lamina, the surface area available for oxidation, and the alloy present. For the semi-rigid packagings, the energy contribution of the aluminium calorific gain was very small; for the flexible packagings with low Al content it varied between 0.2 and 17% (mean 2.6%); and for the flexible packagings with high Al content it ranged between 0.5 and 44% (mean 18.8%).



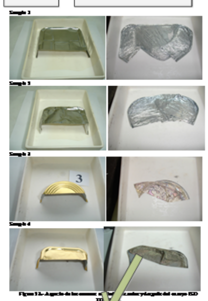
For a calorific gain equal to 0, q_{net} of 1.33±0.21 MJ/kg – the minimum inferior calorific value for the packagings studied

Ash content (ISO 1171:2010)

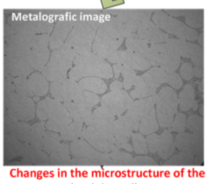
Packaging format	Ash [wt,%]	Al_2O_3 [wt,%]
Semi-rigid (samples 1 – 4)	95.2±4.9	0.8
Flexible A[a] (samples 5 – 15)	10.7±9.6	3.9
Flexible B[b] (samples 16 – 23)	86.2±10.8	9.4

Semi-rigid packaging

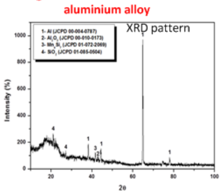
INITIAL | POST-COMBUSTION



Metalografic image



Changes in the microstructure of the aluminium alloy

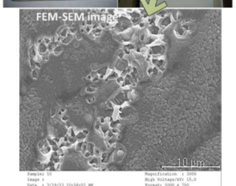


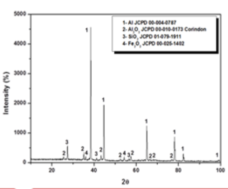
Formation of low content of Al_2O_3 in the surface of post combustion product

Flexible packaging Low Al content

INITIAL | POST-COMBUSTION

FEM-SEM image

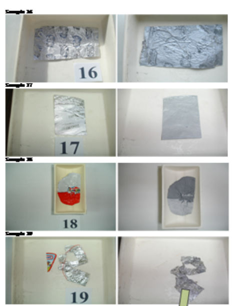




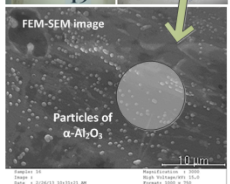
Formation of monolayers of Al_2O_3 (vermicular structure)

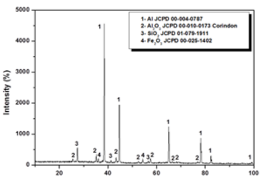
Flexible packaging High Al content

INITIAL | POST-COMBUSTION



FEM-SEM image





Formation of particles of Al_2O_3 in the surface of post combustion product

Conclusions

- ✓ The packagings with a metallic aluminium lamina of between 1 and 122 µm oxidised when heated to a temperature equal to or above the fusion temperature of the metal in a oxygen-enriched atmosphere.
- ✓ Oxidation gives rise to a new layer of α-Al_2O_3 on the metal surface. On some packagings this layer is homogeneous and has a vermicular structure that covers the entire metal surface. In others, the distribution of α-Al_2O_3 is heterogeneous.
- ✓ The aluminium is not totally oxidised; indeed it never exceeds 17%. The degree of oxidation achieved depends more on the metallic aluminium content of the packaging than the thickness of the aluminium lamina.
- ✓ No evidence was seen that the aluminium content became totally oxidised in packagings with an aluminium lamina thickness of <50 µm.

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